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***On Positional Consumption and Technological Innovation
– an Agent-based Approach***

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On positional consumption and technological innovation - an agent-based approach

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Abstract

Positional behavior is a source of externalities and sets limits to wellbeing. Remedies against this market failure are defended by some authors and rejected by others, while the core of the discussion rests on the benefits and costs of applying economic instruments. One of the issues discussed is the role that the competition for positional goods may have in generating technological innovation.

This paper aims to contribute to the understanding of this process by analyzing an agent-based model. We observe a plausible structure of the dynamics behind the process of generation of technological innovation by positional consumption and obtain results on the influence of some key factors on the pace of innovation, particularly those of income inequality, the Hirsch conjecture of relative increase of positional consumption with affluence, and consumer network and social neighborhood sizes.

Keywords: Positional consumption, innovation, agent-based models, Robert Frank

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1 Introduction

The *positional economy* refers to all those goods, services, occupations, or other social relations that are either scarce in an absolute or socially imposed sense, or subject to crowding or congestion through more extensive use. The concept was introduced by Fred Hirsch (1976) in the book "Social Limits to Growth". The idea of a positional economy differs from the classical *material economy*, in which the utility enjoyed with material goods is independent of other individuals' choices. In the material economy, the possibilities to increase the utility of members of society can ultimately be considered limitless, as long as the consumption of additional goods provides any marginal utility to individuals. In opposition, utility gathered in the positional economy depends on the scarcity of the items consumed, a scarcity imposed either physically or socially. With positional consumption, one's utility depends directly on the way other individuals consume the same product. The consumption of status goods is the most eminent case of the positional consumption. The scarcer and most difficult to obtain are the status goods, services or occupations, the more utility they give to the consumer.

Hirsch identifies negative consequences to wellbeing by the positional economy, because the satisfaction of one individual implies the loss of satisfaction by other individuals. In the realm of the consumption of status goods, the nature of the purposes of individuals leads them to a competition over positional goods. However, by definition the net utility provided by status consumption is socially limited, because status is a relative concept; any increase in satisfaction of an individual is formed at the expense of a correspondent decrease in the satisfaction of others. This competition thus results in a zero-sum game and status consumption can consequently be regarded as resource wasteful, since individuals as a whole expend efforts with no aggregate return for the economy.

The description of a useless competitive quest for consumer goods of social significance had been clearly introduced previously by several other authors. Most prominently, Veblen (1899) described the negative aspects and strongly criticized the phenomenon conspicuous consumption and leisure. Galbraith (1958) described what he called the "dependence effect" between wants creation and the process by which they are satisfied, presuming a process positional competition. Easterlin's (1974, 1994) empirical work suggests that increasing the average income of a society does not increase its happiness

level, a result upon which he asserts that "material norms on which judgments of well-being are based increase in the same proportion as the actual income of the society". Several other authors covered this subject before Hirsch, but it never got into the first line of the economics research agenda.

After his observations of positional consumption and economic affluence, Hirsch argued that the inefficiencies to wellbeing caused by positional consumption increases with economic growth: "as the level of average consumption rises, an increasing portion of consumption takes on a social as well as an individual aspect. That is to say, the satisfaction that individuals derive from goods and services depends in increasing measure not only on their own consumption but on consumption by others as well". This presumably happens because, as the economy grows, and with it consumer incomes, a higher share of spending can increasingly be applied in uses other than the basic material needs such as food and habitation. As a consequence, the relative importance of the positional economy over the material economy increases as affluence grows, thereby imposing "social limits to growth".

Hirsch's conjecture originated one of the debates on the origin, consequences and possible remedies of the positional economy. Is indeed the quest for positional goods gaining eminence as the economy grows, thereby increasing inefficiency? Are there benefits from the positional economy offsetting its damage? Should policymakers regard this issue as a matter of state intervention? Hirsch himself assumed a prudent position on policy remedies against it. His prudence was justified by the lack of knowledge of the costs and benefits of applying such kind of policies, although he provided enlightenment on the issues.

The most eminent claim for policy actions for the recoil of the positional economy came from Robert Frank. Frank (1999, 2003, 2005) compares the competition for positionality e.g. with an arms race between two countries, where mutual escalation of expenditure on armaments driven by fear for political independence, does not enhance security for either nation. The overall effect is a reduced welfare, for the extra spending comes at the expense of domestic consumption. Positional consumption should therefore be faced as an externality, in the sense that positional climbing from an agent increases the effort of other agents needed to maintain their own positions. Frank argues that the State should intervene and as a policy remedy he advocates progressive consumption taxes. Progressive consumption taxes would discourage high-end consumption and consequently erode the "expenditure

cascade” that follows.

Critics of Frank generally do not question that positional consumption is a market failure (Frank, 2006). However several do question that it should be a matter of state intervention. Kashdan and Klein (2006) present a set of arguments against taxation on positional consumption, arguing that Frank “overstates the problem, overlooks various voluntary solutions, overlooks unintended consequences of using taxation, and neglects the Smithian incumbency on those proposing coercion” .

One of the arguably unintended consequences of positional taxation is that it will reduce the positive effect of positional consumption in its role as a driver of technological innovation. Cited by Kashdan and Klein, Hayek has stated the importance of high-end consumption to innovation: “What today may seem extravagance or even waste, because it is enjoyed by the few and even undreamed of by the masses, is payment for the experimentation with a style of living that will eventually be available to many” (Hayek 1960). In this respect Kashdan and Klein add that “in the dynamics of a growing economy, the wealthy provide a market for goods that must be expensive in order to supply to be viable. The wealthy pay extra to enjoy the benefits of new goods, which, if suitable to human existence, will later become inexpensive and widely adopted”. To internalize the costs of the competition for positional goods would therefore cease the positive externalities of this mechanism to innovation.

In reply to Kashdan and Klein, Frank (2006) countered this argument by stating that the alternative capital allocation caused by positional taxation would also drive technological innovation. In the short run, Frank argues, “the tax would not change the total level of spending. Rather, it would shift the composition of spending in favor of investment”, which would drive capital goods innovation. Frank additionally argues that the higher rates of investment would, in the long run, cause consumption level to increase in relation to the low-savings trajectory through income growth.

Several and complex matters interfere with the way positional consumption may or may not generate socially desirable technological innovation, and how far. An objective evaluation of the extent to which positional consumption generates a process of technological innovation seems unattainable on practical grounds. However, at a theoretical level we could at least envisage a better understanding of the issues at stake.

In this paper we aim to achieve a better comprehension of the dynamics

of the process of generation of technological innovation through positional consumption. In that view, we build an agent-based model which stands for the generation of technological innovation by the competition for positional goods. The results of its simulation allow to observe in detail the dynamics of this process. Besides it, we observe the influence of some relevant factors on the pace of innovation. These factors are, namely, the level of income inequality of the consumer society, the materialization of the Hirsch conjecture and the size and structure of the network of positional consumers.

2 Is positional consumption an effective way of generating technological innovation?

Frank's (2006) point on the role of alternative capital allocations to positional consumption towards technological innovation shows that, even accepting that positional competition has a positive effect over innovation, there are no *a priori* reasons to believe that positional taxation reduces innovation because the increase in investment capital allocation generated also has positive effects over innovation in the short run and even more so in the long run.

Whether the outcome of positive effects over innovation is better in the short run in a *laissez faire* or a taxed positional economy, depends simply on either it is the first or the second case that directly generates the highest innovation. In the long run the answer is less straightforward, depending also on the dynamical effects of innovation and investment. If, in the short run, innovation is higher in the positional taxation scenario, it is clear that it will also be higher in the long run. However, if the *laissez faire* scenario produces higher short run innovation, both outcomes would still be possible in the long run depending on whether the additional short run innovation of the *laissez faire* scenario would generate enough income growth to offset the income growth driven by additional investment in the positional taxation scenario.

In order to respond to the question of whether it is more beneficial to the development of technological innovation to have it being generated through positional consumption or through other means of capital allocation, it would be necessary to objectively assess benefits over innovation of both alternatives. Focusing on the positional competition alternative, one would in this

regard aim to assess whether or not its process generates technological innovation and, if so, in what extent.

The answer certainly depends largely on what the particular object of positional competition is, and on which attribute of the good is valued for status. For example if the positional good in question is the automobile, and its positional attribute is solely its brand name, then the associated positional behavior will not generate technological innovation. It will instead plausibly cause prices to be maintained at a high level to promote the top status of the brand thanks to the limited number of consumers who can afford such a car. On the contrary, if the positional attribute of the car is its driving performance, or its comfort, then positional competition should be a source of technological innovation directed at that positional attribute.

Another issue is that of the benefits of the type of innovation in question to society. Even if positional consumption does produce technological innovation, such innovation can only be regarded as positive for wellbeing in the extent to which it is able to address material needs, in addition to positional needs, for only the satisfaction of the former need is susceptible to increase wellbeing. For example, if we assume that the odor of a perfume solely satisfies positional needs, then technological innovation directed at improving the smell of perfumes can not increase wellbeing because the additional satisfaction of one's needs (of smelling good, in relation to others) motivated by innovations in the chemistry of the substance is done at the expense of the satisfaction of the remaining.

In view of these matters, the question of whether positional consumption is an effective process of generating technological innovation should be broken down into three questions:

- Does positional consumption contribute to the generation of any technological innovation?
- If so, in what measure?
- And finally, is the generated technological innovation welfare enhancing (i.e. does it address material needs)?

In this paper we focus on the comprehension of the process by which technological innovation is generated by competition for positional goods. With that aim, a representative model of the process is used which tries to characterize the process and conditions determining the pace of innovation. We are therefore focusing mainly on the second issue, i.e. the intensity of

technological innovation generated. The condition of the first question above as taken as true - i.e. the type of good considered is one over which there is a positional competition directed at an attribute susceptible of technological innovation - whereas the issue of effects on welfare is not covered here.

To analyze the level of technological innovation generated, the model includes several factors which affect the pace of innovation. The factors analyzed are income inequality, the occurrence of the Hirsch conjecture and the size and nature of the network of positional consumers.

3 A Model of Positional Consumption and Technological Innovation

An agent-based modelling (ABM) approach seems to be most appropriate choice for modeling the relation between positional consumption and technological innovation, due to the fundamental role that interactions between agents (consumers and firms) have in the development of the process. Axelrod and Tesfatsion (2005) remark that "when the interaction of the agents is contingent on past experience, and especially when the agents continually adapt to that experience, mathematical analysis is typically very limited in its ability to derive the dynamic consequences. In this case, ABM might be the only practical method of analysis". The process of technological innovation generated by positional consumption corresponds to this area of problems. In fact, unlike for classical material consumption, when positional consumers evaluate the expected utility from the acquisition of a given good, they do it by observing the distribution of goods possessed by all the other consumers in their relevant social network. Therefore the evolution of their decisions is fully interdependent with past decisions of other agents. A feedback loop occurs in this chain of events, whereby a decision of a consumer is determined by the decisions of the remaining consumers, which are later influenced by that same decision. The same goes for the decisions of firms to engage in the creation of new, more technologically advanced goods. Such decisions depend on their expectations on future revenues produced by the new goods, and therefore by the distributional structure of goods possessed by the consumers in the social network(s), which is on its side also contingent on the possible previous creation of new goods. In short, the nature of the

process is characterized by the existence of interacting agents, by the contingency of their decisions on past decisions and by the existence of feedback loops, all elements that make a mathematical approach difficult to realize.

Our agent-based model intends to represent the process of interaction between positional consumption of status goods and the possible generation of technological innovation through the creation of more advanced goods. For such it is designed to contain the most elementary features of both positional consumption and the development of innovative goods as a function of the consumers' willingness to pay. The focus is therefore mainly on representing *(i)* a consumer valuation of goods based on status grounds (utility depends on other consumers' choices), *(ii)* the behavior of firms over technological innovation contingent on expected revenues, and also *(iii)* the consideration of a progressive price decrease of existing goods due to increasing competition between firms and production process efficiency. The designed model aimed to contain these features in a simple form. A detailed description follows.

The model is characterized by the following **agents**:

- C consumers, characterized by different levels of income;
- The industry, which is a single agent representing the aggregate behavior of firms in the economy;

The fundamental structural **assumptions** of the model are described below:

- There is one type of good, with a technological attribute that provides consumers with status;
- Consumers aim to maximize individual utility; utility is obtained through status;
- There is a G number of versions of that type of good¹, each being characterized by having different levels of technological development;
- The utility provided by a good to a consumer depends on the technological level of the good and on the choices of the other consumers; the higher is the technological hierarchy and the least consumers have that version or superior versions of the good, the higher is the positional utility conferred by the good;

¹Versions of the good under study are further simply designated as *goods*.

- The utility obtained in each simulation period is valid for that period only; consumers buy a good in each simulation period to obtain utility for that period;
- The budget of the consumer for buying a good in each period is determined by his income;
- Consumers' choices depend on the expected utilities provided by the goods, their prices and the available incomes of consumers; consumers have different willingness to pay for utility depending on their incomes.
- The industry can create a technologically more advanced good; to do that it must incur in research & development (R&D) for its development; a technologically more advanced version is created if the expected demand for the new version is able to exceed the R&D costs necessary for its development;
- When a new good is created, the industry sets its price at the level that maximizes revenues from sales, taking into account the number of consumers that would buy the good at each possible price;
- The price of the existent versions of the good decrease with time due to increasing competition of supply and production process efficiency.

Figure 1 describes the sequence of steps of the model run. It consists of a cyclical sequence in which consumers observe the choices of other consumers, form expectations of the utility derived from each possible version of the good and decide which good to buy. Then the industry evaluates the possible advantage of developing a technologically more advanced good and decides whether or not to create the good. Finally, the prices of goods are updated and the following period starts.

The formal specification of the model setup is described in the following sections.

Consumer Network

A consumer is influenced by a set of consumers, in his preferences over positional goods. The model is built on a network in which each consumer is influenced by a group of other consumers, in line with Frank and Levine's (2007) description of the interactions affecting consumer preferences over positional goods.

The social classes are defined in the model by income levels. The neighborhood $N(i)$ of a consumer i consists of the set of his N_s closest individuals

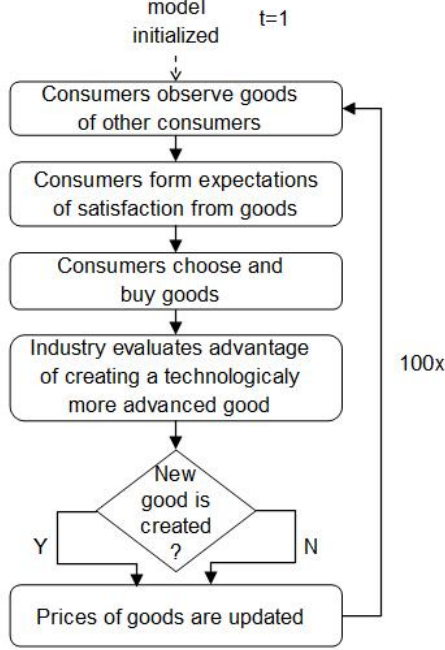


Figure 1: Model structure

in the income ranking ², being N_s the size of the neighborhood. The formal definition of neighborhood is as follows:

$$N(i) := \begin{cases} N_p(i) & \text{if } \frac{N_s}{2} < i \leq C - \frac{N_s}{2} \\ N_p(1 + \frac{N_s}{2}) & \text{if } |i - 1| < \frac{N_s}{2} \\ N_p(C - \frac{N_s}{2}) & \text{if } |C - i| < \frac{N_s}{2} \end{cases} \quad (1)$$

where $N_p(i)$ is the pseudo-neighborhood of i and is given by:

$$N_p(i) := \{j \in I : |i - j| \leq \frac{N_s}{2}\} \quad (2)$$

²For the purposes of this paper, a Ranking characterizes the hierarchical order of subjects before a given attribute. The ranking is a sequence of integers between one (1) and the number of subjects characterized by the ranking (C). Rankings are attributed by decreasing order of the attribute values of subjects. In this case, the subjects are the consumers and the attribute in their income.



Figure 2: Examples of neighborhood in a network of 10 consumers with a neighborhood size of 4

where I is the set of consumers.

As stated in equation 1, the neighborhood of each consumer depends on his relative position on the income ranking. All consumers have the same number of neighbors, therefore low-end and high-end consumers have an asymmetric neighborhood with more neighbors on one side of the income ranking than the other side, due to finiteness of the set of consumers. This definition implies that connections are unidirectional, i.e. where a consumer is influenced by the choices of another consumer the opposite may not necessarily happen. Figure 2 illustrates examples of consumer neighborhoods.

Consumer Incomes

Consumers have different levels of income, which increase with the index i representing individuals. Consumer incomes (W) follow a Weibull distribution curve, with a cumulative form given by:

$$F(W(i), \bar{W}, k) = 1 - \exp\left(-\left(\frac{W(i)}{\bar{W}}\right)^k\right) \quad (3)$$

with $W(i) \geq 0$ and \bar{W} being the average income.

The Weibull curve allows to represent various configurations for the distributions of incomes, ranging from unequal to even distributions. The degree of (in)equality of the distribution depends on the constant k . The following Figure represents three possible curve profiles, depending on k :

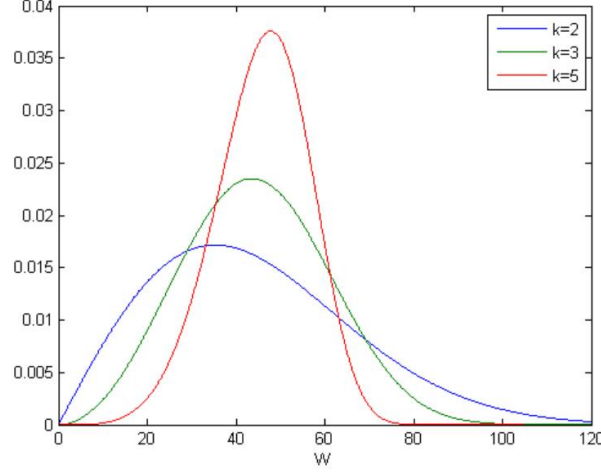


Figure 3: Possible profiles for income distributions characterized by a Weibull distribution

Consumers are willing to spend up to a fraction qp of their income in positional functionalities. Fraction qp would be actually spent by the consumer in the positional functionality if the good purchasable with that amount would allow him to reach the maximum possible utility derived from the positional functionality. This assumption is described in further detail below.

Prices of Goods

Each good g has a price $P(g)$. The prices of goods decrease with time due to increasing competition of supply and production process efficiency. Prices of goods evolve according to a negative exponential given by:

$$P(k) = P_{comp} + (P_{launch}(g) - P_{comp}) \cdot \exp\left(-\frac{t-t_0(g)}{k_p}\right) \quad (4)$$

where P_{comp} is the competitive market price - i.e. the price when there is full competition for the commercialization of the good and production efficient

is maximized (in the long term) - $P_{launch}(g)$ is the price of a good g set by the industry in the period of its launch in the market, t is the present time, $t_0(g)$ is the period of creation of good g and k_p is a constant that determines how slow the price decreases³.

Utilities

The positional utility provided by a good depends on: how high that good is positioned in the technological hierarchy, and; on the hierarchies of the goods possessed by the other consumers. The value of the maximum achievable utility is one (1) and occurs if the consumer possesses the higher good in the technological hierarchy and no other consumers possess the same good. The minimum possible utility is zero (0) and occurs if all the remaining consumers possess goods of higher hierarchy than that of the individual. The positional utility for an individual i for buying a good g is given by:

$$U(i, g) = \frac{N_{inf}(i, g) + \frac{1}{2} * N_{eq}(i, g)}{N_s} \quad (5)$$

where $N_{inf}(i, g)$ is the number of neighbors in the social influence network (neighborhood) of individual i who buy technologically inferior goods than g and $N_{eq}(i, g)$ is the number of consumers in the social influence network of the individual i who buys equivalent goods (i.e. good g itself).

In words, having a superior good than that of another consumer within the influence neighborhood provides twice the positional utility of having the same good as another consumer, while having an inferior good does not give any positional utility.

The utility provided by the good only lasts for the period of its acquisition, expiring at the beginning of the following period. Therefore the consumers have to buy a new good in a period to achieve any utility at that period.

Finally, it is implicitly assumed that material utility does not influence the choices of consumers; either the goods provide no material utility or they all provide the same.

Consumer choices

The consumer's choice of a good in each period depends on his willingness to pay for utility, which is a function of his income. In each period, the

³ $k_p=20$ in all simulations below.

consumer chooses the good with the better trade-off between price and utility. It is assumed that consumers do not downgrade their previous choices, i.e. they do not consider buying a given good if they have previously bought a more technologically developed one at some point in time.

The model assumes that, for taking a decision, the consumer compares pairs of goods. In each comparison, his preference is determined by the differences of potential utilities provided by the goods being compared and by his willingness to pay for utility. When comparing between goods g_m and g_n , the consumer chooses g_m if the difference in utilities between g_m and g_n is higher than the ratio between their difference in prices and the consumer's maximum budget assignable to the positional functionality. Formally, the choice falls on g_m over g_n if the following condition is met:

$$U(g_m) - U(g_n) \geq \frac{P(g_m) - P(g_n)}{W(i) * qp} \quad (6)$$

The consumer is willing to give a proportion qp of his income in return for $U_{max}=1$, therefore his willingness to pay for utility is $W(i) * qp$.

An assumption of the model is that consumers base their decisions on expected utilities, which are formed under the supposition that all other consumers maintain the options made in the previous period.

Innovation: creation of new goods

Technological innovation is reflected in this model by the creation of new, technologically more advanced goods. The more goods are created during the simulation time, the more investment in innovation happens.

In each period, a new and technologically more advanced good may be created by the industry. For that to happen, the industry must invest a given amount in R&D (Crd). A new good is developed if the potential revenue (R_{pot}) derived by its hypothetical sales in the following period is higher than the R&D costs that would be involved in its creation:

$$R_{pot} > Crd \quad (7)$$

The cost of R&D efforts necessary to create the new good is given as a ratio f of the total income of consumers in the economy (W_{total}). Fixing R&D costs in terms of total income allows us to test effects of income distribution.

$$Crd = W_{total} * f \quad (8)$$

The potential revenue from a hypothetical new good is calculated on the basis of the price that would maximize the difference between revenues obtained from its sales and those obtained if the good would not be created, considering the number of consumers that would be willing to buy the good at that price:

$$R_{pot} = \max_i \{ (P_{max}(i, g_{new}) - P(g_{high})) * (C - i + 1) \}, i \in H \quad (9)$$

where g_{new} is the hypothetical new good, g_{high} is the present good with the highest ranking, H is the group of consumers which consumed g_{high} and $P_{max}(i, g_{new})$ is the maximum price that the consumer i would be willing to offer for the newly more advanced good, with:

$$P_{max}(i, g_{new}) = P(g_{high}) + (U(g_{new}) - U(g_{high})) * W(i) * qp \quad (10)$$

4 Results

4.1 Scenarios

The model was aimed at the comprehension of the process of technological innovation through the competition for positional goods. Its simulation allowed us to observe the structure of dynamics behind positionality driven innovation, as well as testing the influence of relevant factors towards the pace of innovation, particularly:

- **Income inequality** (k); as described above, income inequality has been pointed out by prominent authors as a factor that promotes the market generation of technological innovation, and is consequently pointed as an argument against the application of instruments aimed at recoiling the process of competition for positional goods like the progressive consumption tax.
- **Proportion of income allocatable to positional consumption** (qp); testing this factor corresponds to testing the effects of the materialization of the the Hirsch conjecture, of growing positional relative spending with wealth increase.
- **Size and type of consumer network** (c); it is interesting, from the social network analysis perspective, to observe the effects over technological

innovation that may arise from different sizes of the population of consumers and the extension of social influence through social classes.

The set of simulations realized was formed by a baseline simulation, and further sets of simulations aimed at studying the influence of factors outlined here. The term *innovation*, or pace of innovation, refers here to the total number of new goods created during the simulation time.

Parameters		Population of consumers	Consumer neighborhood size	Parameter for income inequality	Income fraction for posit. cons.	R&D costs (fraction of total income)	Consumption frequency
Scenarios		C	N_s	k	qp	f	
Baseline	0	100	C-1	2	50%	2%	1
Income inequality	1.1	100	C-1	0.1 to 500	50%	2%	1
	1.2	100	C-1	0.1 to 500	50%	1.25%	1
Hirsch conjecture	2.1	100	C-1	2	0% to 150%	2%	1
	2.2	100	C-1	2	0% to 150%	2%	2
Number of consumers	3	1 to 500,000	C-1	2	50%	2%	1
Social Neighborhood (function of f)	4.1.1	100	2 to C-1	2	50%	0.5%	1
	4.1.2	100	2 to C-1	2	50%	1.25%	1
	4.1.3	100	2 to C-1	2	50%	2%	1
	4.1.4	100	2 to C-1	2	50%	3%	1
Social Neighborhood (function of k)	4.2.1	100	2 to C-1	0.5	50%	2%	1
	4.2.2	100	2 to C-1	1	50%	2%	1
	4.2.3	100	2 to C-1	2	50%	2%	1
	4.2.4	100	2 to C-1	3	50%	2%	1

Legend: White cells represent baseline values ; Grey cells represent tested values

Table 1: Model inputs

In the tested set of simulations some quantitative assumptions are applied: R&D costs for the creation of a new product are a fraction of total income (f) of 2%; the competitive market price for each good (P_{comp}) is equal to zero (0), therefore prices of goods tend to zero in the long term; at the first period of simulation there are 3 goods with different prices and technological levels, and; the simulation runs for 100 periods of time.

The key parameters of the analyses performed are k , qp , C and N_s , respectively accounting for income inequality, maximum fraction of income

spent in positional consumption, size of the consumer population and size of the consumer social neighborhood respectively. The values of R&D costs (f) and consumption frequency are also varied in some subscenarios. Table 1 describes the set of scenarios tested.

4.2 Baseline simulation - modelling positional competition and technological innovation

In the baseline simulation, the model takes an inequality coefficient (k) of 2 - a value similar to those found in typical societies⁴ - , a maximum fraction of consumer income potentially expendable in the positional functionality (qp) of 0.5 - half the consumers' income - , a population (C) of 100 consumers with all consumers influencing each other - i.e. with a social neighborhood size (N_s) of 99 - and R&D costs being a fraction of total income (f) of 2%.

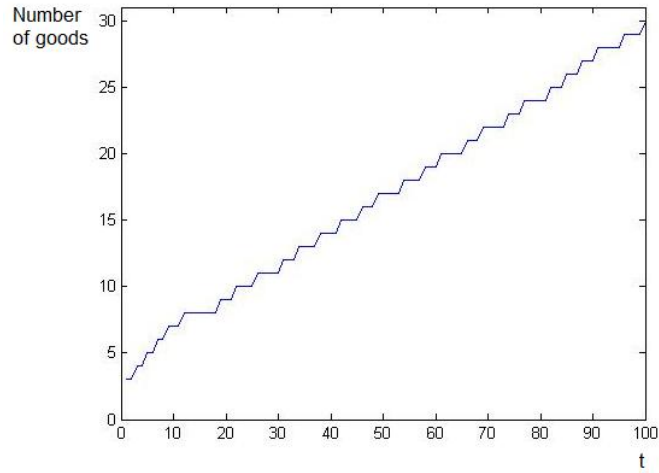


Figure 4: Number of goods over time

The results reveal a cyclical creation of new and technologically more developed goods driven by competition for positional goods. In the first periods of the simulation the consumers make their choices, according to their

⁴A k of 2 is equivalent to a Gini index of 0.251 or a Hoover index of 0.219

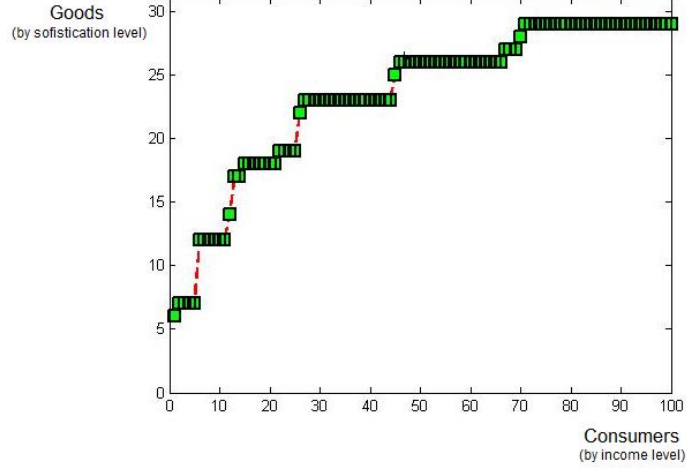


Figure 5: Matching between consumers and goods, at the end of simulation ($t = 100$)

preferences, amongst the goods available in the market. After the matching between consumer preferences and the available goods, a latent demand for the consumption of a more technologically advanced good eventually surges and grows. As soon as the expected revenues for the industry for putting a more technologically advanced good into the market exceed the R&D costs necessary for its development, the good is actually developed and the latent demand is satisfied. The matching between consumers and goods is renewed at each period, a process which dynamically evolves both through the evolution of the positional attributes of the goods - which change each time any consumer alters its choice - and the downtrend of prices of goods through time due to increasing competition and the efficiency of production process.

Figure 4 shows the number of goods in each period of time. New goods are created at a relatively stable rate, except in the warm-up time (up to about the 20th period). At the end of the simulation, there are 30 goods in total, i.e. 27 new goods are created at a cycle of new product development being about 3,7 periods. Figure 5 shows the matching between consumers and goods at the last period of simulation. Consumers at the high end of income are consuming goods at the high end of sophistication, and consumers

at the low end of income are consuming the less sophisticated goods. The three initial goods have no longer any buyers. It is noteworthy that in this last period the good with the highest number of consumers is good number 29, which was, when consumers made their decisions, the most sophisticated one available. But as is possible to see in Figure 4, a new good is finally created in this period (good number 30), which happens precisely as a result of the fact that many consumers were already consuming the highest level good, enabling a strong latent demand for a new good.

The main result of this dynamics of "competition" for positional goods together with a continuous price downtrend is a cyclical creation of more technologically advanced goods.

4.3 Income inequality

As we have seen above, the degree of inequality depends on the value of k in the Weibull curve that defines income distribution among the population of consumers. To check for effects of inequality over the level of innovation in the model, simulations were run with different values of k . The Figure below shows the results obtained. It also shows the Hoover index - a measure of (in)equality - for the spectrum of tested k values. The higher is the Hoover index - and k - the most equitable is the defined income distribution.

The general trend observed is that the dynamics of technological innovation improves with equality, although this trend is broken for values of k sensibly between 2 and 3. This result holds for different values of R&D costs (f), as is seen in Figure 6.

The relation between the pace of innovation and level of equality depends on two opposing drivers. In an unequal society, high-end consumers are willing to individually spend very large amounts of money to obtain positional utility, but there are not many consumers in that position. In a fairly equal society, high-end consumers do not have, in relative terms, so much funds, but there is a much larger pool of consumers with incomes very close to the highest earnings level. In this situation, despite the fact that high-end consumers are not willing to spend as high as in the unequal society, they together have a powerful multiplying effect. It is the balance between these two variants - price of the new good and number of consumers willing to pay for it - that determines whether technological innovation increases or decreases with the level of equality. In our model, the massification of high-end

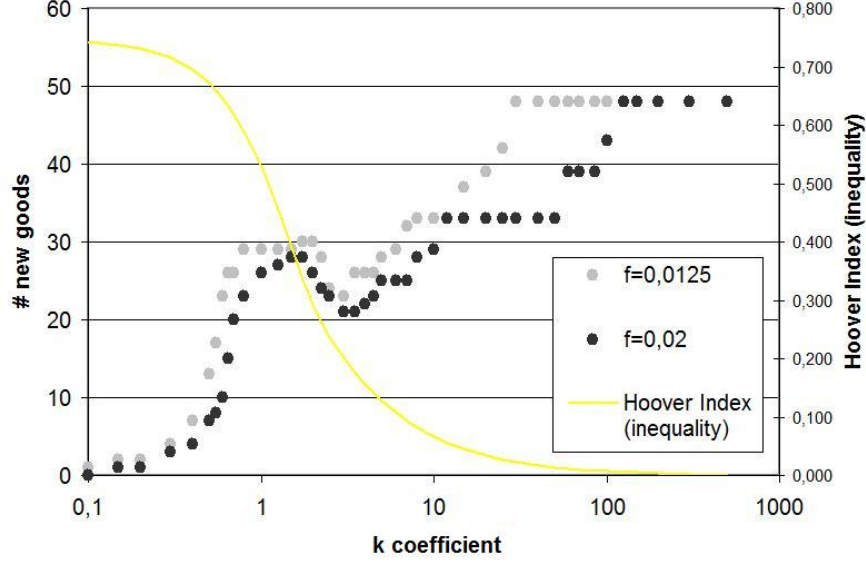


Figure 6: Number of new goods with different income distributions

consumption is, in the large majority of the income distribution setups, a stronger driver of technological innovation than the relative wealth of the richest consumers.

Back to the argument of Kashdan and Klein, inspired by Hayek, that in the dynamics of a growing economy it is the wealthy that enable a market for goods necessarily expensive for its supply to be viable, this result shows that it is possible to have an even more viable market for new goods with a lower price for those goods, as long as there is a larger pool of consumers economically able to compete for the highest positional places (i.e. a less unequal society).

On the other hand, at first thought the result of our model may seem not to support the conjecture put forward by Frank (2003) and Frank and Levine (2005) that inequality drives positional expenditure cascades. However, their argument is grounded on the observation that the savings rate of middle class has been decreasing with the increase of inequality, whereas our model takes income available for positional spending as a constant (qp) fraction of income.

4.4 Hirsch Conjecture

According to Hirsch, "social limits to growth" are imposed by the fact that the relative importance of the positional economy over the material economy increases with affluence growth. When basic material needs of consumers get satisfied, they tend to increase their share of income to positional means ⁵.

We analyze consequences, on the dynamics of innovation, of the materialization of the Hirsch conjecture. Model simulations with different shares of consumption dedicated to positionality show decreasing returns of innovation to the share of allocatable income to positional spending. This would imply that "social limits to growth" would apply also to the "innovation factor" of positional consumption.

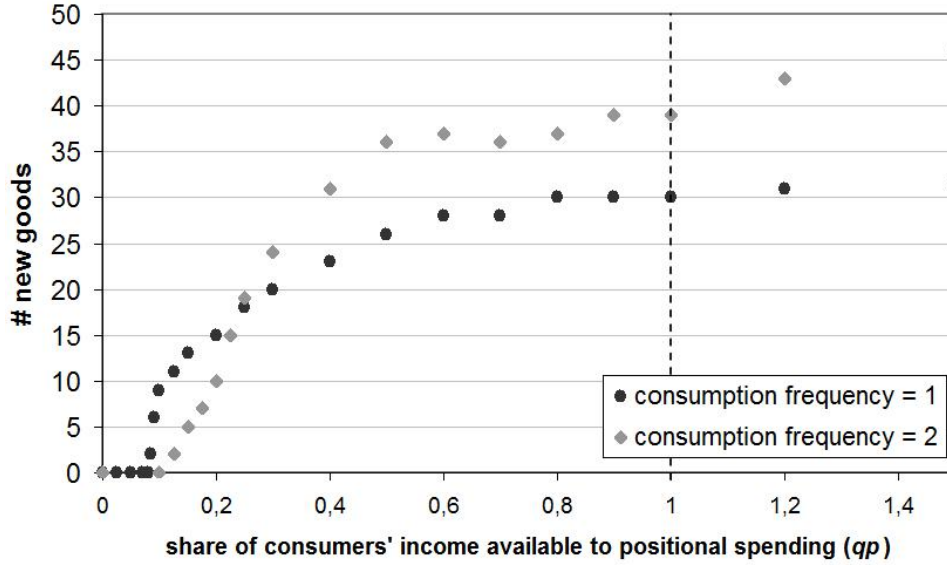


Figure 7: Number of new goods as a function of the share of consumer income available to positional spending

However, this result of decreasing returns of innovation to positional consumption is subject to the assumption of the model that consumers exert

⁵Brekke et al (1998) note although that this may not be true, depending on the specification of the utility function of consumers).

their positional stakes (by consuming) at a constant rate (one good is bought at each period; its utility is valid for one period). It is plausible to expect positional stakes to be played more frequently as the budget available for positional consumption also increases. On this, the model shows that different frequencies of consumption may return different volumes of innovation; comparing the initially assumed consumption frequency of 1 with a consumption frequency of 2 (two goods consumed in each period) results show that (Figure 7) that the lower frequency returns more innovation for low levels of relative budget allocatable to positional spending whereas the higher consumption frequency returns more innovation for high levels of positional budget. This suggests that, if the increment of positional spending carries with it an increase in consumption frequency, then the result of decreasing returns of innovation to positional spending would not necessarily occur. The nature of the relation between positional spending and innovation therefore depends also on the relation between positional spending and the frequency of positional consumption. In this respect, we remark nevertheless that the increase of frequency of positional consumption must have its own limits, posed by the finite pace at which consumers are able to incorporate information on changes in the "positional market". Only when consumers actually realize changes in their positional ranking and available positional goods can they form and deliver their consumption decisions.

4.5 Consumer network

The positional competition for goods occurs within its own societal context. When one individual evaluates his *position* or that of other individuals in the social ranking, he does so within his perceived social sphere, i.e. within the group of individuals with whom he regards as belonging to his group of influence.

On one hand, one may discuss whether this social arena for positional competition is regarded by individuals as a large group of other individuals, like a region or a country, or on the contrary as a very small circle of close connections in the individual's particular social context, like family and closest acquaintances. In this scope context it is interesting to test for the level of innovation occurring before different sizes of the social population (still assuming a fully connected influence neighborhood) are tried.

The model produces very stable results (Figure 8) before variations in

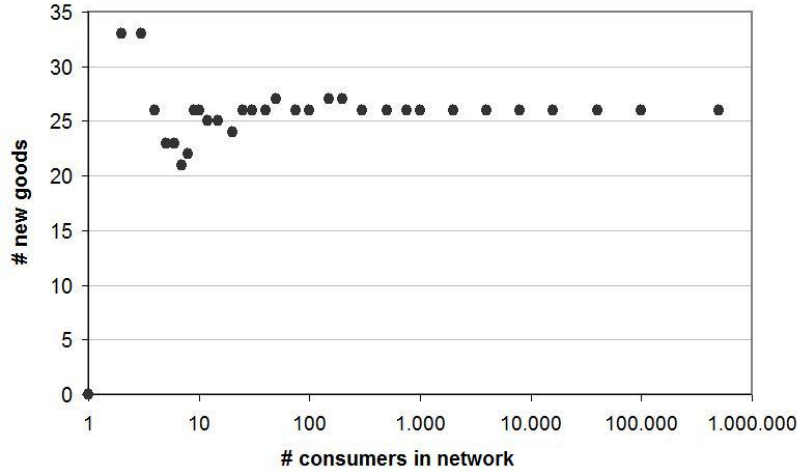


Figure 8: Number of new goods as a function of number of consumers

population size, except for very low sizes of the social network (less than 10 agents) where the number of goods produced can vary no more than 25% of the commontypical innovation output. Therefore, the size of the relevant social network for positionality shows no relevant effects on the speed of innovation, unless very small networks are considered.

On the other hand, we may question the importance of the nature and size of the influence group affecting each consumer's choices (named above as the consumer neighborhood). We admitted a consumer neighborhood defined by proximity in social class (or level of income); a consumer is influenced - in his evaluation of the utilities given by different goods - by his closest neighbors in the social ranking. This accounts for a world where people compare themselves to friends, work colleagues and residential neighbors, i.e. people who tend to belong to a similar income group.

Translating this question to the real world, the relevant focus would be less on the proportion and quantity of consumers within the whole population accounting for one's neighborhood, but rather on the extension of one's influence group to social classes different than its own. In the example above, a neighborhood consisting of all the consumers in the network would translate into a society where an individual would be influenced indifferently by

any other individuals, disregard of their social class. Such was the case in the simulations presented above. On the other hand, a small neighborhood in our model is analogous to a world where individuals compare their positional achievements with other individuals with a very similar social class.

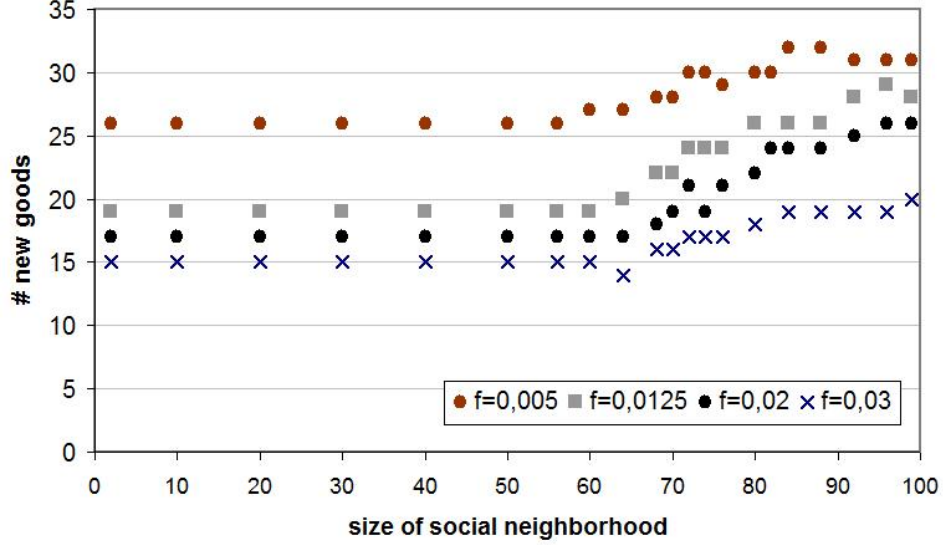


Figure 9: Number of new goods as a function of size of social neighborhood, with different investment costs of R&D

Taking the baseline population of 100 consumers, we simulated different neighborhood sizes to account for its effects on the creation of new goods. In the first set of simulations, different levels of R&D investment costs were tried (f). The baseline value for inequality was taken ($k=2$).

The simulated results for this inequality scenario have shown a perfectly stable amount of new goods for neighborhood sizes up to about 60% of the total number of consumers, whereas higher neighborhood sizes produced increasing levels of innovation. The result is robust for different levels of required investment on R&D, as shown in Figure 9. Although the explanation for this outcome is not straightforward, we know that ultimately the creation of new goods depends on the aggregate willingness to pay of the high end consumers. Apparently, the willingness to pay of the group with the highest

potential revenue for the industry is affected by the size of the social neighborhood only with neighborhood sizes relatively close to the total number of consumers, case in which the potential income tends to increase.

However, this particular result, which assumes a given inequality profile ($k=2$), is not generalizable. In fact, testing neighborhood sizes with other inequality profiles produces quite distinct results. As we can see in Figure 10, not only the partial non-dependence between neighborhood size and innovation does not occur for other income distributions, but also the direction of the observed relation varies largely with income distribution and differentially with neighborhood size. A high equality level ($k=3$) results in a null relation, for the number of new goods produced is invariable. On the other hand, a society with a high inequality ($k=0.5$) produces results with disparate differential relations between neighborhood size and level of innovation.

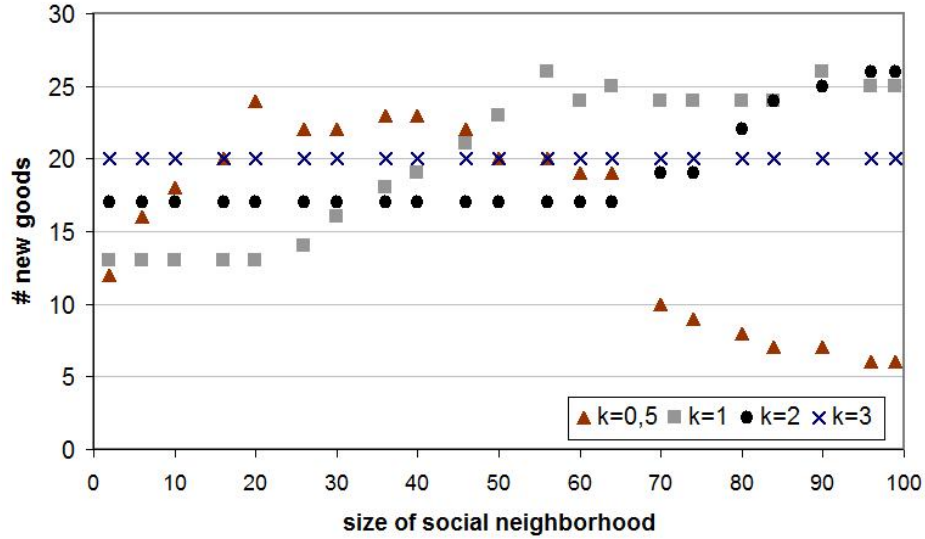


Figure 10: Number of new goods as a function of size of social neighborhood, with different income distributions

The relation between types of networks of social interaction and the generation of innovation is complex, and depends highly on the income distribution. It seems not to be possible to clearly infer a profile for this relation in

the real world, which is likely to vary largely from place to place depending on the structure of society.

Scenarios	Main Results
0. Baseline	Cyclical creation of new and technologically more developed goods driven by competition for positional consumption and price downtrend.
1. Income inequality	The general trend observed is that the dynamics of technological innovation improves with income equality, although with local changes to this positive trend. It is the outcome between price of the innovative good and number of consumers willing to pay for it that determines whether technological innovation increases or decreases with the level of equality. In our model, the second element is therefore stronger in most cases.
2. Hirsch conjecture	Model shows decreasing returns of innovation to the share of income allocatable to positional spending. This would imply that "social limits to growth" would apply also to the innovation generated by positional consumption.
3. Number of consumers	Size of the relevant social network for positionality shows no relevant effects on the speed of innovation, unless very small networks are considered.
4. Social Neighborhood	The relation between size of neighborhood of social interaction and the generation of innovation is complex, and depends highly on the income distribution. It seems not to be possible to clearly infer a profile for this relation in the real world, which is likely to vary largely from place to place depending on the structure of society.

Figure 11: Summary of results

The table in Figure 11 summarizes the main findings provided by the results of the simulations presented above.

5 Summary and Conclusions

With the aim of contributing to the comprehension of the relation between positional consumption and technological innovation of products, we devel-

oped a model that represents the process of technological development generated by the competition for consumption of positional goods.

In this model, the positional utility of goods is connected to their technological attributes and consumers periodically play their stakes in the positional game by consuming one type of good. There are different versions of the type of good which differ in their technological level. New, more technological advanced, versions of the good are developed and put into the market by the industry whenever the expected revenues of sales are higher than the costs of R&D for developing the more technologically advanced version. Simultaneously, prices of new goods decrease with time due to increasing competition and productive efficiency. Periodically the consumers evaluate the expected positional utility achieved from each version of the good against their available budgets and correspondingly place their decisions on which one to buy.

This process of competition for positional goods associated with the possibility of creation of new goods and their progressive price decrease generates a cyclical development of technologically more developed goods. The pace of innovation depends on several model parameters, namely the number of consumers, the amount of R&D costs for the creation of new goods, the pace of decrease of prices, income inequality, the relative preferences of consumers for positional goods over other types of spending and the type of influence network of the consumers. We tested for the effects of variations of some of these parameters over the pace of innovation, namely income inequality, the materialization of the Hirsch conjecture and the size of the population of consumers and the size of the social neighborhood of positional influence.

Before different levels of income inequality, the model globally produces a negative relation between income inequality and the number of new goods created, although with oscillations in this rule accross the possible spectrum of income distribution profiles. This result has shown that, contrary to a conventional argument, the market for innovation may happen to be higher in less unequal societies.

To check the consequences of the Hirsch conjecture on innovation, testing different shares of positional spending showed decreasing returns of innovation to positional spending. This would imply that the "social limits to growth" imposed by increasing positional spending would also apply to the associated process of technological innovation, although this result depends on the assumption that the frequency of consumption is rigid. Although fre-

quency of consumption is likely to increase with wealth, we note that it must also have its own limits, if not for other reasons at least due to restrictions in the ability of positional consumers to obtain information on the positional market.

Finally, the relation between the social neighborhood size of positional influence and the generation of innovation was seen as a complex one, highly dependent on income distribution. According to the results of the model, the profile of this relation in the real world varies largely from place to place, depending on the structure of society.

References

- [1] Araujo, T. and R. Vilela Mendes. 2006. *Market-oriented innovation: When is it profitable? An abstract agent-based study*, Working Paper, UECE.
- [2] Araujo, T. and R. Vilela Mendes. 2009. *Innovation and Self-Organization in a Multi-agent Model*, Advances in Complex Systems, v.12, pp 233-253.
- [3] Arthur, W. Brian. 1994. Inductive Reasoning and Bounded Rationality (The El Farol Problem), Amer. Econ. Review (Papers and Proceedings), 84, pp 406.
- [4] Axelrod, R. and Tesfatsion, L. 2005. A Guide for Newcomers to Agent-based Modeling in the Social Sciences, Appendix in Handbook of Computational Economics, vol. 2, pp 1647-1659.
- [5] Brekke, K. A., Howarth R. B., Nyborg, K.. 1998. *Are there Social Limits to Growth?*, Discussion Papers No. 239, November 1998, Statistics Norway, Research Department.
- [6] Brekke, K. A. and Howarth, R. B.. 2000. *The Social Contingency of Wants*, Land Economics, November 2000, 76 (4): 493-503.
- [7] Dawid, Herbert. 2006. *Agent-based Models of Innovation and Technological Change*, Chapter 25 in Handbook of Computational Economics, vol. 2, pp 1235-1272.

- [8] Easterlin, R. A. 1994. *Will raising the incomes of all increase the happiness of all?*, Journal of Economic Behavior and Organization, Vol. 27, pp 35-47.
- [9] Ellis, A. and Heath, A. 1983. *Positional Competition or an Offer You Can't Refuse*, In. A. Ellis & K. Dumat (Eds.), Dilemmas of Liberal Democracies, pp. 1-22, London: Tavistock.
- [10] Frank, R. 1999. *Luxury Fever*, Princeton University Press, Princeton.
- [11] Frank, R. 2003. *Are Positional Externalities Different From Other Externalities?*, Draft for presentation at The Brookings Institution.
- [12] Frank, R. 2005. *Positional Externalities Cause Large and Preventable Welfare Losses*, American Economic Review, 95(2), pp 137-41.
- [13] Frank, R. 2006. *Taking Libertarian Concerns Seriously: Reply to Kashdan and Klein*, Econ Journal Watch, Volume 3, Number 3, pp 435-451.
- [14] Frank, R. and Levine, A. S. 2007. *Expenditure Cascades*, paper presented at the 2007 American Economics Association Conference, Chicago.
- [15] Galbraith, J. K. 1958. *The Affluent Society*, Houghton Mifflin Company, New York.
- [16] Hayek, F. A. 1960. *The Constitution of Liberty*, Chicago: The University of Chicago Press.
- [17] Hirsch, F. 1976. *Social Limits to Growth*, Harvard University Press, Cambridge, Massachusetts.
- [18] Howarth, R. B. and Brekke, K. A. 1998. *Status Preferences and Economic Growth*, Discussion Papers No. 240, November 1998, Statistics Norway, Research Department.
- [19] Kashdan, A. and Klein, D.B. 2006; *Assume the Positional: Comment on Robert Frank*, Econ Journal Watch, Volume 3, Number 3, pp 412-434.
- [20] Mason, R. 2000; *Conspicuous Consumption and the Positional Economy: Policy and Prescription Since 1970*, Manage. Decis. Econ. 21: 123132.

- [21] Veblen, T. 1899. *The Theory of the Leisure Class*, Viking Compass Edition published 1967.
- [22] Vriend, N. J. 2006. *ACE Models of Endogenous Interactions*, Chapter 21 in Handbook of Computational Economics, vol. 2, pp 1047-1079.
- [23] Wilhite, A. 2006. *Economic Activity on Fixed Networks*, Chapter 20 in Handbook of Computational Economics, vol. 2, pp 1013-1045.